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Technical note

Growth, intake, diet digestibility, and nitrogen use in three hair sheep breeds fed alfalfa hay☆

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Abstract

Pen feeding and metabolism trials were conducted to determine intake, diet digestibility and nitrogen (N) use in three hair sheep breeds with differing growth potential offered an alfalfa hay diet. For pen feeding, 24 6-mo-old wether lambs, equally representing the Barbados Blackbelly, Katahdin, and St. Croix breeds, were paired by breed, placed in 12 enclosed cement-floor pens (2.5 m × 3.5 m), and offered chopped alfalfa (*Medicago sativa* L.; 17.6% CP, 50.4% NDF, and 36.4% ADF) ad libitum. Lambs were allowed a 14-d adaptation period to pens and diets, and remained on trial for 56 d. Starting body weight (BW) was different ($P < 0.05$) among breeds (Barbados Blackbelly: 23.8 kg; Katahdin: 36.5 kg; St. Croix: 29.1 kg). Daily gain was not different ($P < 0.10$) between Katahdin (131 g/d) and St. Croix (117 g/d), but both were higher ($P < 0.05$) than Barbados Blackbelly (87 g/d). Daily dry matter hay intake was similar among breeds (107–109 g/kg $BW^{0.75}$), and feed to gain ratio ranged from 8.7 in St. Croix and 9.1 in Katahdin to 10.5 in Barbados Blackbelly, but was not different ($P > 0.10$) among breeds. Six lambs per breed were used in the metabolism trial. Total DMI was greater ($P < 0.01$) for Katahdin (1196 g/d) than St. Croix (907 g/d) and Barbados Blackbelly (858 g/d), but was not different ($P > 0.10$) adjusted for body weight (mean: 71 g/kg $BW^{0.75}$). Coefficients of apparent digestibility for DM ($P < 0.06$), OM ($P < 0.06$), N ($P < 0.05$), NDF ($P < 0.08$), and ADF ($P < 0.08$) were higher for Katahdin compared to Barbados Blackbelly with St. Croix intermediate. Intake of N ($P < 0.01$), feces N ($P < 0.08$), urine N ($P < 0.01$), absorbed N ($P < 0.01$), and retained N ($P < 0.05$) also were greater for Katahdin compared to St. Croix and Barbados Blackbelly. Blood glucose, urea-N, and creatinine were not different ($P > 0.10$) among breeds. Breeds differed in their growth performance in line with breed mature size, and differences were observed in N digestibility and absorption.

Keywords: Hair sheep; Alfalfa; Growth; Digestibility; Blood metabolites

1. Introduction

Interest in hair sheep production in the U.S. has been increasing with a declining return on wool production, an increased acceptance of smaller carcasses in non-traditional markets, and a shift towards forage-based production (Notter, 2000). Hair sheep are generally smaller in size and have lower growth rates than more traditional wool sheep, but are reputed to be more tolerant to gastrointestinal parasites, to have an increased ability to breed out-of-season, and to be better able to utilize low to moderate quality forages than the traditional breeds (Wildeus, 1997). Target weights of lambs for ethnic markets are lower than for lambs produced for the traditional markets, and the potential of hair sheep to achieve these

☆ Trade names are used for the convenience of the reader and do not imply endorsement by Virginia State University or USDA over comparable products.

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weights on forage-based diets without additional supplementation needs to be evaluated.

When fed high-concentrate finishing diets, hair sheep lambs have lower growth rates than wool breeds and hair × wool crosses (Ockerman et al., 1982; McClure and Parker, 1991; McClure et al., 1991; Phillips et al., 1995; Bunch et al., 2004). However, Silva et al. (2004) showed that hair breeds (Santa Inês) had a higher OM intake and utilized diets with an increasing forage component more efficiently than temperate wool breeds (Ile de France cross). Comparing the performance of lambs grazing either legume or grass pasture with lambs receiving an all-concentrate diet in dry lot, McClure et al. (1994) observed higher daily gains in dry lot lambs, though growth of lambs grazing alfalfa approached that of dry lot lambs, while producing leaner carcass with a more desirable yield grade.

Hair sheep breeds currently found in the U.S. include the Barbados Blackbelly and St. Croix, two landrace breeds derived from earlier importations from the Caribbean, and the Katahdin, a composite breed upgraded from the St. Croix. The Katahdin was developed through crossing with various wool breeds, while retaining a hair coat, and selecting for meat-type conformation and high fertility. The three breeds vary in mature size, and Horton and Burgher (1992), evaluating physiological differences in small numbers (3–4 animals/breed), detected breed differences in growth rate, feed-to-gain ratio, and feed and water intake. The objective of this study was to further evaluate forage intake and utilization by the three hair sheep breeds when offered alfalfa hay diets.

2. Materials and methods

The experiment was conducted at the Small Ruminant Facilities of Virginia State University, Petersburg, Virginia (pen feeding trial), and the USDA, ARS, Appalachian Farming Systems Research Center, Beaver, West Virginia (metabolism trial). Care of lambs, and the research protocols used in the two trials were approved by the Institutional Animal Care and Use Committees at the two institutions, and followed accepted guidelines (FASS, 1999).

Hair sheep ram lambs ($n = 24$) for the experiment were recruited from a July-born lamb crop, and equally represented the Barbados Blackbelly, Katahdin and St. Croix breeds, with a minimum of three lambs per sire per breed. Ewes that produced the lambs were managed as one flock, except during mating (single sire mating with two sires per breed). Lambs were weaned at 9 wk of age. Ram lambs were castrated after weaning, and all lambs maintained as one group on pasture until the initiation of the experiment at 6 mo of age. Pre-trial, postweaning ADG was 100, 110, and 109 g/d for Barbados Blackbelly, Katahdin, and St. Croix, respectively.

2.1. Pen feeding trial

Animals were paired within breed and pairs randomly assigned to one of 12 enclosed cement-floor pens (2.5 m × 3.5 m) equipped with automated waterers. Forage was fed in 120 l capacity plastic bins fitted with a 0.3 m × 0.3 m opening for access to forage. Animals were allowed a 14-d adaptation period to pens and diet, remained on trial for 56 d, and body weight was recorded in 14 d intervals. Animals had ad libitum access to a trace-mineralized salt lick with ammonium chloride throughout the feeding trial.

Lambs were fed an all-forage diet of alfalfa hay (*Medicago sativa* L.; 17.6% crude protein, 50.4% neutral detergent fiber, 36.7% acid detergent fiber) chopped to a particle length of 6 cm, and fed at >125% of estimated intake. Hay offered and hay refused was recorded daily, and every 7 d after routine weekly pen cleaning hay spillage was recorded and used to adjust daily intake.

2.2. Metabolism trial

After the pen feeding trial 18 lambs, equally representing the three breed types, were selected at random and transferred together with the alfalfa hay to the USDA-ARS Appalachian Farming System Research Center for the metabolism trial. Animals were allowed to adjust to metabolism crates for 3 d prior to the start of the experiment, and were then offered the alfalfa hay for 10 d followed by 4 d of total collection of feed, orts, feces, and urine. Prior to the start of the 4-d total collection period, one St. Croix lamb was injured and was removed from the study. During the 4-d total collection period, animals were offered hay adjusted to 90% of the previous 10-d voluntary intake; sub-samples of hay collected during these 4 d were composited. During the 4-d collection, orts were weighed, and a 10% sub-sample was obtained, dried at 100 °C, and used to adjust intakes. Total feces and urine were collected in plastic buckets; urine buckets contained 50 ml of 6N HCl. Feces were weighed and urine volume measured and weighed prior to taking a 10% aliquot, and compositing for each animal. Blood samples were collected via jugular venipuncture at the end of the 14-d trial period.

Table 1
Body weight, growth, feed intake and feed: gain ratio in three hair sheep breeds fed an all-forage (alfalfa hay) diet (pen feeding trial)

	Breed			S.E.	*P* value
	Blackbelly	Katahdin	St. Croix		
Start BW (kg)	23.8 a	36.5 c	29.1 b	2.9	<0.001
Final BW (kg)	29.2 a	44.7 c	36.5 b	3.6	<0.001
ADG (g/d)	87 a	131 b	117 b	26	<0.02
DMI (%) BW	3.31 b	2.93 a	3.10 ab	0.18	<0.05
DMI (g/d/kg $BW^{0.75}$)	109	107	107	0.67	NS
Feed:gain ratio	10.53	9.11	8.73	1.43	NS

Values in same row with unlike letters differ significantly ($P < 0.05$).

2.3. Sample analysis

Daily fecal sub-samples were dried at 60 °C in a forced-air oven for 1 wk and then composited. Acidified urine samples were stored at −20 °C. Blood samples were allowed to clot for 45 min and centrifuged (1500 × *g*) for 20 min to obtain serum. Aliquots of serum were stored at −20 °C until analyzed for urea-N, glucose, and creatinine concentrations using automated procedures on the Ciba-Corning Express Plus Chemistry Analyzer (Ciba-Corning Diagnostics Corp., Medfield, MA).

Dried hay and fecal samples were ground to pass a 1-mm screen in a Wiley mill. Ground hays, supplement, and dried fecal samples were analyzed for: DM and ash (AOAC, 1990); total N (Carlo-Erba Ea 1108 CHNS elemental analyzer, Fisons Instruments, Beverly, MA); and neutral detergent fiber (NDF) and acid detergent fiber (ADF) using ANKOM (Ankom Technology Corp., Fairport, NY) procedures. Apparent digestion coefficients for DM, OM, N, NDF and ADF and nitrogen retention were calculated.

2.4. Statistical analysis

Data were analyzed for the effect of breed on pen hay intake, pen average daily gain, and pen feed to gain ratio (pen feeding trial), and individual animal hay and water intake, apparent DM, OM, N, NDF, and ADF digestibility, N balance, and blood serum metabolites (metabolism trial) using GLM procedures of SAS (1996). Contrasts between breeds were determined using the PDIFF option in the presence of a significant *F* value, and values are presented as least squares means.

3. Results

3.1. Pen feeding trial

Although body weights were significantly different ($P < 0.05$) for all three breeds at the beginning and end of the trial, daily gain was not different ($P > 0.10$) between Katahdin and St. Croix (131 and 117 g/d, respectively), but both gained more rapidly ($P < 0.05$) than Barbados Blackbelly (87 g/d) (Table 1). Dry matter hay intake as percentage of body weight was higher ($P < 0.05$) in Barbados Blackbelly than in Katahdin, with St. Croix intermediate, but was not different ($P > 0.10$) among breeds when adjusted for metabolic body weight ($BW^{0.75}$) (Table 1). Feed to gain ratio was not different ($P > 0.10$) among breeds, and ranged from 8.73 in St. Croix to 10.53 in Barbados Blackbelly.

3.2. Metabolism trial

Initial body weights of animals in the metabolism trial were reflective of the weights of the three breeds at the

Table 2
Body weight (BW), dry matter intake (DMI), and water intake in three breeds of hair sheep fed all-forage (alfalfa hay) diets (metabolism trial)

	Breed			S.E.	*P* value
	Blackbelly	Katahdin	St. Croix		
BW (kg)	26.5 a	41.8 c	32.1 b	1.3	<0.001
DM intake (g/d)	858 a	1196 b	907 b	61	<0.01
DMI (g/d/kg $BW^{0.75}$)	74	73	67	0.4	NS
Water intake (ml/kg BW)	10.5 b	7.4 a	6.9 a	0.7	<0.01
Water intake (ml/kg $BW^{0.75}$)	23.9 b	18.9 a	16.3 a	1.6	<0.02

Values with unlike letters in same row differ significantly ($P < 0.05$).

Table 3
Apparent in vivo digestibility coefficients in three hair sheep breeds fed all-forage (alfalfa hay) diets (metabolism trial)

Digestibility (%)	Breed			S.E.	*P* value
	Blackbelly	Katahdin	St. Croix		
Dry matter (DM)	58.3 a	63.0 b	59.3 ab	1.4	<0.06
Organic matter (OM)	58.6 a	63.4 b	59.7 ab	1.4	<0.06
Nitrogen (N)	67.7 a	72.3 b	69.4 ab	1.3	<0.05
NDF	41.8 a	49.0 b	43.6 ab	2.2	<0.08
ADF	38.5 ab	44.0 b	36.5 a	2.2	<0.08

Values with unlike letters in same column differ significantly ($P < 0.05$).

Table 4
Nitrogen (N) balance in three breeds of hair sheep fed all-forage (alfalfa hay) diets (metabolism trial)

	Breed			S.E.	*P* value
	Blackbelly	Katahdin	St. Croix		
N intake (g/d)	24.1 a	33.6 b	25.5 a	1.7	<0.01
Feces N	7.8 a	9.3 b	7.7 a	0.5	<0.08
Urine N	13.5 a	18.9 b	15.4 a	1.0	<0.01
Absorbed N	16.3 a	24.3 b	17.8 a	1.3	<0.01
Retained N	2.8 a	5.4 b	2.4 a	0.8	<0.05
Percent of N intake					
Feces N	32.3 b	27.7 a	30.6 ab	1.3	<0.05
Urine N	56.4	56.3	60.5	2.3	NS
Absorbed N	67.7 b	72.3 a	69.4 ab	1.3	<0.05
Retained N	11.3	16.1	8.9	2.8	NS
Percent of absorbed					
N retained	16.2	22.3	12.7	3.9	NS

Values with unlike letters in same column differ significantly ($P < 0.05$).

end of the pen feeding trial (Table 2). Total DMI of alfalfa hay was greatest ($P < 0.01$) for Katahdin (1196 g/d) compared to St. Croix and Barbados Blackbelly, which were not different (mean 883 g/d). Daily DMI adjusted for metabolic body weight (mean 71 g/kg $BW^{0.75}$) were not different ($P > 0.10$) among breeds (Table 2). Water intake was greater ($P < 0.01$) for Barbados Blackbelly (10.5 ml/kg BW) compared to Katahdin (7.4 ml/kg BW) or St. Croix (6.9 ml/kg BW).

Coefficients of in vivo digestibility for DM and OM tended to be higher ($P = 0.06$) for Katahdin compared to Barbados Blackbelly; St. Croix were intermediate (Table 3). The in vivo N digestibility was higher ($P < 0.05$) for Katahdin compared to Blackbelly; with St. Croix again being intermediate. The in vivo digestibility of NDF also tended to be higher ($P = 0.08$) for Katahdin compared to Barbados Blackbelly, while in vivo digestibility of ADF tended ($P = 0.08$) to be higher compared to St. Croix (Table 3).

Nitrogen balance data are presented in Table 4. Intake of N ($P < 0.01$), feces N ($P = 0.08$), urine N ($P < 0.01$), absorbed N ($P < 0.01$), and retained N ($P < 0.05$) were greater for Katahdin compared to St. Croix and Barbados Blackbelly, which were similar. These differences were related to a higher DMI by Katahdin lambs. When expressed as a percentage of N intake, feces N and

Table 5
Pre-prandial blood serum metabolites in three hair sheep breeds fed all-forage (alfalfa hay) diets (metabolism trial)

	Breed			S.E.	*P* value
	Blackbelly	Katahdin	St. Croix		
Urea-N (mg/dl)	22.6	25.5	22.7	1.3	NS
Glucose (mg/dl)	73.2	70.7	76.1	2.2	NS
Creatinine (mg/dl)	0.65	0.62	0.60	0.03	NS

absorbed N were higher ($P < 0.05$) in Katahdin compared to Barbados Blackbelly, with St. Croix intermediate. Urine N and retained N expressed a percentage of absorbed N was not different ($P > 0.10$) among breeds. Blood parameters were not different among the breeds (Table 5).

4. Discussion

The growth rates of the forage-fed lambs (87–131 g/d) were higher than those reported in Barbados Blackbelly and Barbados Blackbelly × Dorset lambs fed coastal bermudagrass pellets (50 g/d; Mann et al., 1987), or in St. Croix lambs fed tropical Guinea grass (−27 to 34 g/d; Hammond and Wildeus, 1993). When forage-based diets were supplemented with concentrate feeds, growth rates increased to 67–165 g/d, dependent on forage quality and level of concentrate supplementation (Wildeus et al., 2001, 2003, 2004). St. Croix lambs fed concentrate feedlot diets achieved growth rates as high as 259 g/d (Foote, 1983) and 210 g/d (Bunch et al., 2004), but these growth rates were always lower than those of contemporary St. Croix × wool crossbred and wool lambs in these studies. No differences in growth rate between purebred St. Croix and wool breed × St. Croix lambs pen-fed a complete pelleted ration were reported under tropical conditions (Godfrey and Collins, 1999).

Katahdin are considered an improved breed type, with a higher growth potential than the Barbados Blackbelly and St. Croix landrace breed types, however, their growth rate here was similar to that of St. Croix. In a previous study at our facility, Katahdin had a higher growth rate of 129 g/d, compared to 85 and 76 g/d in St. Croix and Barbados Blackbelly, when fed a grass hay-based diet supplemented with concentrate at 2% BW (Wildeus et al., 2001). In follow-up trials, no breed differences in growth rate between Katahdin and St. Croix were observed when comparing alfalfa or grass hay-based diets (Wildeus et al., 2004), or when concentrate supplementation was reduced to 0.75% BW (Wildeus et al., 2003). Burke et al. (2003) actually observed a higher post-weaning gain in St. Croix (205 g/d) than Katahdin lambs (181 g/d) fed a totally mixed finishing diet. In the current trial the absence of a concentrate component in the diet may have prevented Katahdin lambs to express their higher growth potential.

Dry matter intake in Barbados Blackbelly lambs fed alfalfa here (109 g/d/kg $BW^{0.75}$) was higher than those fed coastal Bermuda grass (95 g/d/kg $BW^{0.75}$; Mann et al., 1987), and still higher in Barbados Blackbelly rams fed tropical forage (*Digitaria decumbens*; 53 g/d/kg $BW^{0.75}$; Archimede et al., 1999), indicating a higher DMI as forage quality improved. Similar to the findings here, Mann et al. (1987) observed no differences in DMI between breed types in purebred and Barbados Blackbelly × wool (Dorset) crossbred lambs. In contrast, Horton and Burgher (1992) feeding a concentrate diet, found higher DMI in Katahdin (150 g/d/kg $BW^{0.75}$) and Dorset lambs compared to St. Croix (117 g/d/kg $BW^{0.75}$) and Barbados Blackbelly (129 g/d/kg $BW^{0.75}$), and Pineda et al. (1998) found a reduced intake in purebred Pelibuey (90 g/d/kg $BW^{0.75}$) compared to wool × Pelibuey crosses (139 g/d/kg $BW^{0.75}$) fed a feedlot diet in the tropics. This would suggest that DMI in hair sheep was affected by breed type when concentrate, but not forage-based, rations were fed.

Little information is available on the feed to gain ratio of hair sheep fed forage-based diets. The feed to gain ratio of St. Croix lambs on the forage diet provided here (8.7), was higher than that of St. Croix lambs receiving concentrate diets, that ranged from 5.0 (McClure et al., 1991) to 6.9 (Bunch et al., 2004) and 7.2 (Phillips et al., 1995). In these studies feed to gain ratio was less efficient in the purebred St. Croix lambs than in contemporary wool and hair × wool crossbreds, while no difference in feed to gain ratio (6.6) was observed by Horton and Burgher (1992) between Katahdin, St. Croix and wool (Dorset) lambs fed a concentrate diet. In contrast, under tropical conditions Godfrey and Collins (1999) reported lower feed to gain ratios in adapted purebred St. Croix (6.6) compared to wool × St. Croix crossbreds (8.8–9.6). Additional studies are needed to determine the effects of breed type and environment on feed efficiency of hair sheep breeds.

In the metabolism trial DMI was not different among breeds, and was reduced by 30% compared to pen feeding (67–74 g/d/kg $BW^{0.75}$). Mann et al. (1987) reported similar DMI (70 g/d/kg $BW^{0.75}$) and no breed differences in Barbados Blackbelly and Barbados Blackbelly × Dorset cross lambs fed coastal bermudagrass pellets, but detected a higher DMI in Barbados Blackbelly lambs (70 g/d/kg $BW^{0.75}$) than crossbred lambs (60 g/d/kg $BW^{0.75}$) when chopped orchard grass-alfalfa hay was fed. No such breed type × forage form interaction was observed by Quick and Dehority (1986), feeding either pelleted, chopped or long alfalfa-bromegrass hay to St. Croix and Targhee cross lambs. Intake differences observed in our study appeared to be strictly a function of body weight, rather than breed type. Dry matter, OM, NDF and ADF digestibilities, restricted to 90% of the previous 10-d intake in order to minimize orts, were reduced in Barbados Blackbelly lambs compared to Katahdin (Table 3), likely as the result of Barbados Blackbelly lambs compensating by increasing

DM intake (%BW; as was observed in the pen feeding study here) and rate of passage (not measured here) in order to satisfy energy requirements (Mertens, 1993).

The higher water intake observed in Barbados Blackbelly than St. Croix and Katahdin here was not in agreement with results by Horton and Burgher (1992) reporting a higher water intake in Katahdin than in Barbados Blackbelly, with St. Croix intermediate. Differences may be the result of climatic conditions as well as diet, as absolute water intake was higher in other studies (Quick and Dehority, 1986; Archimede et al., 1999).

The breed differences in DM digestibility between Barbados Blackbelly and Katahdin here were not observed by Mann et al. (1987) between Barbados Blackbelly and Barbados Blackbelly × Dorset crosses, or by Quick and Dehority (1986) between hair (St. Croix) and wool breeds. In contrast, Silva et al. (2004) reported a higher DM digestibility coefficient in hair than wool cross lambs fed forage-based diets with different levels of concentrate supplementation in Brazil. The breed type differences in DM digestibility coefficients between these experiments may be related to differences in forage types and quality, and environmental conditions.

The finding of an increased crude protein digestibility coefficient and improved N balance in Katahdin compared to Barbados Blackbelly is consistent with the results of Mann et al. (1987) who detected higher crude protein digestibility in Barbados × wool crossbred lambs compared to purebred Barbados Blackbelly and wool lambs. Silva et al. (2004) reported a higher crude protein digestibility and a higher level of N retention in Santa Inêz (hair) than wool cross lambs fed forage-based diets, but also observed an increased DMI and CP intake (g/kg $BW^{0.75}$) in the hair lambs. These authors suggest a higher utilization of recycled N as a mechanism for the improved N balance, which should also be considered for the Katahdin lambs here.

Blood metabolites were used to monitor nutrient status (glucose and urea-N) and associated muscle mass (creatinine), but no differences were noted among the breeds. Differences in N utilization among breeds were apparently not of sufficient magnitude to be reflected in blood urea-N concentrations (Kohn et al., 2005). Horton and Burgher (1992) observed higher blood urea-N concentrations in Katahdin than Barbados Blackbelly lambs, and lower glucose concentrations than in St. Croix, which reflected the trends in blood metabolites concentrations observed here.

5. Conclusions

Growth of the hair sheep lambs on an alfalfa hay diet without supplementation was moderate, and did not allow the Katahdin, as an improved hair sheep breed, to express its higher growth potential compared to St. Croix. Dry matter intake (g/kg $BW^{0.75}$) of the alfalfa hay diet was similar among breeds, but Katahdin lambs had a higher apparent digestibility of most feed fractions compared to the Barbados Blackbelly lambs, and utilized available N more efficiently than the other two breeds.

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